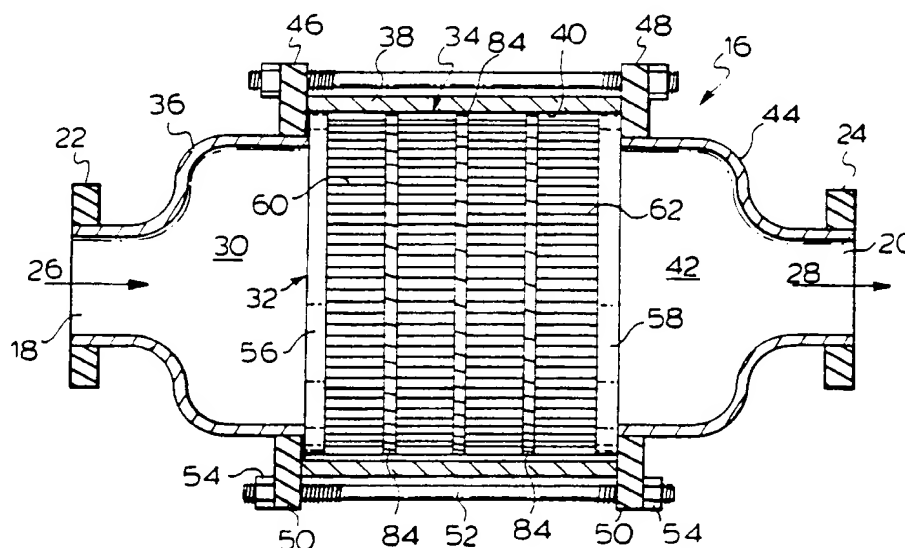


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(54) Title: FLAME ARRESTOR APPARATUS



## (57) Abstract

An apparatus for extinguishing a flame travelling along a pipe where the travelling flame is characterized as any type of deflagration flame or detonation flame, comprises: i) a housing with an inlet and an outlet and means for connecting the inlet and outlet to a pipe, ii) a flame extinguishing device, iii) means for securing the device in the housing, iv) the device having a plurality of serially arranged elements, each element having a plurality of longitudinally extending channels, v) a turbulence device positioned between adjacent elements and having surfaces for inducing turbulence in the flame flow through the elements, vi) the housing sealing the elements in a manner to direct flame flow solely through the elements and the turbulence inducing devices.

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FLAME ARRESTOR APPARATUSFIELD OF THE INVENTION

This invention relates to flame arrestor apparatus particularly useful for extinguishing any type of travelling deflagration flame or detonation flame.

BACKGROUND OF THE INVENTION

A flame arrestor apparatus, usually comprises flame extinguishing elements which have very small diameter, typically less than 0.040 inch diameter channels that permit gas flow but prevent flame transmission by quenching or extinguishing combustion. This results from the transfer of heat (enthalpy) from the flame (high temperature) to the solid matrix of channels (low temperature) which effectively provide a substantial heat sink.

The quenching process is based on the drastic temperature difference between the flame and channel matrix material. As such, this is a transport process that not only depends on the temperature gradient, but also on the channel hydraulic diameter and the thermal conduction (diffusivity) properties of the gas.

The rate of heat loss from the flame is significantly affected by the level of turbulence within the flame arrestor channel. The turbulence is associated with the flow of unburnt gas through the flame arrestor as instigated by the pressure rise that accompanies a flame front to the element. The flame induced flow is always in the same direction as the impinging flame travel. The pressure rise can range from a small fraction to more than 100 times the initial (pre-ignition) absolute pressure in the system.

Two of the most common types of flame arrestor elements are the crimped ribbon type such as described in U.S. patent 4,909,730 and the parallel plate type as described in Canadian patent 1,057,187. The major advantage of these constructions is that it is possible

to build a device with a fairly large percentage of open flow area per unit cross section while maintaining precise channel dimensions. This is very important because flame arrestors are often used in installations  
5 where large volumes of gas must be vented with minimal back pressure on the system. It is generally understood that even small deviations in channel dimensions can compromise flame arrestor performance. These can be referred to as straight path flame arrestors because the  
10 gas flow takes a straight path from the channel entrance to the exit.

A major disadvantage of the straight path units is that they do not extract heat from the flame very efficiently. One method commonly used by designers to  
15 overcome the low heat transfer efficiency of straight path units is to further reduce the hydraulic diameter of the straight path channels. This is intended to increase heat transfer efficiency by increasing the lateral area of heat loss per unit volume of flame front. However,  
20 the diameter reduction further increases the tendency for laminar flow which in turn further reduces heat transfer. The channels of reduced diameter also become clogged and fouled by liquids or particles that are usually present in the system.

Another method frequently used to overcome the low  
25 heat transfer efficiency of straight channels is to design an element consisting entirely of tortuous path channels. Examples of these include, stacked expanded metal or wire mesh, sintered metal or ceramic, packed  
30 beads and steel wood plug. The disadvantages of tortuous path elements is that they clog readily, are difficult to clean, and they have unacceptably high flow pressure drops, resulting in the need for excessively large element flow cross sections.

35 There are several examples of these types of systems, as given in prior patents. Examples of wire mesh systems are described in U.S. patent 1,701,805 and

Canadian patent 666,952. The wire mesh element comprises a plurality of layers which function as a flame flow interrupter. Other systems which develop tortuous paths for the gas flow are described in Canadian patents  
5 565,942 and 709,337. Such tortuous paths are provided by beads, particles and the like which are also used in a system described in U.S. patent 2,044,573.

A system which involves crimped ribbon and laminar flow channels for the flame arrestor element are  
10 described in U.S. patents 2,087,170; 2,789,238 and 3,287,094.

Other types of systems involve nesting of plates, such as described in U.S. patents 1,826,487; 1,960,043; 2,068,421; 2,186,752; 2,618,539; 2,758,018 and 3,903,646.  
15 In these flame arrestors the plates are nested in a manner to provide flame extinguishing properties by transfer of heat from the flame front to the flame arrestor element.

As noted, the difficulty with these flame arrestor  
20 systems is that the channels through which the flame front flows causes a laminar flow in the flame front. This is detrimental from the standpoint of arresting high pressure flames, particularly detonations. It has been found however that in order to ensure extinction of the  
25 detonation type of flame, additional modifications must be made to the arrestor having a wire mesh plate or crimped metal design. In U.S. patent 4,909,730 a detonation attenuating device is positioned upstream of the flame quenching elements. Testing has demonstrated  
30 that the presence of the cup-shaped detonation attenuating device to attenuate impinging shock waves due to detonation significantly improves the overall performance of the flame arrestor having the standard type of crimped metal heat transfer flame arresting  
35 elements. However, the use of the detonation attenuator cup causes significant flow restrictions in the gas

exhausting system and complicates manufacture of the device.

Although systems have been provided which can arrest flame fronts of the deflagration or detonation type, such systems require the use of element designs which develop significant back pressure. Designs which enhance heat transfer of the flame front to the arresting element have the overriding flow limiting factor of small diameter channels which induce laminar flow and hence, reduce the effectiveness of heat transfer from the flame front to the elements due to the boundary layer effect of the laminar flow through the small diameter channels of the element. There therefore continues to be a need for a flame arresting device which can extinguish all types of travelling flames ranging from deflagration types through to the very high pressure detonation types without overly restricting normal gas flows through the arrestor.

#### SUMMARY OF THE INVENTION

The apparatus according to this invention incorporates special elements which enable normal designs for arrestor elements to extinguish or quench the various types of travelling flames ranging from low pressure deflagration flames through to high pressure detonation flames.

According to an aspect of the invention, an apparatus is provided for extinguishing a flame travelling along a pipe where the travelling flame is characterized as any type of deflagration flame or detonation flame. The apparatus comprises:

- i) a housing with an inlet and an outlet and means for connecting the inlet and the outlet in a pipe,
- ii) a flame extinguishing device,
- iii) means for securing the device in the housing,
- iv) the device including a plurality of serially arranged elements, each element having a plurality of longitudinally extending channels,

v) means for inducing turbulence in flow of flame through the elements, the turbulence inducing means being positioned between adjacent elements and having surfaces for inducing turbulent flow in flame exiting an upstream element and before entering a downstream element to enhance thereby heat transfer from a travelling flame into the elements,

vi) the device having a sufficient number of elements to extinguish any type of flame travelling along a pipe in which the apparatus is connected, and

vii) means for sealing the elements to the housing to direct flame flow solely through the elements and the turbulence inducing means.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are shown in the drawings, wherein

Figure 1 schematically shows a flame arrestor within a vent pipe for an oil tank,

Figure 2 is a section through the flame arrestor of Figure 1,

Figure 3, which accompanies Figure 1, shows the stacked elements in accordance with the preferred embodiment of this invention,

Figure 4, which accompanies Figure 2, is an exploded view of the turbulence inducing device positioned between two flame arrestor elements,

Figure 5 is an exploded view of adjacent elements with the turbulence inducing device positioned therebetween,

Figure 6, 7 and 8 are enlarged views of various types of turbulence inducing devices, and

Figures 9, 10 and 11, which accopanies Figure 5, are enlarged views of alternative forms of flame arresting elements.

#### DETAILED DESCRIPTIONS OF THE PREFERRED EMBODIMENTS

It is appreciated that flame arrestors or, in more general terms, apparatus for extinguishing or quenching

flames, are used in a variety of applications, such as demonstrated in the discussion of prior art systems. It is therefore intended that Figure 1 represent one of the uses of the flame arrestor of this invention. A storage  
5 tank 10 for the flammable liquid which produce flammable gases has a vent pipe 12. In the normal manner, the vent pipe 12 has a flare 14 for burning the off gases. The common problem with this arrangement is that the flare 14 may develop an flame front which flows back through the  
10 pipe 12 into the tank 10 causing an explosion within the tank. The purpose of the flame arrestor 16 is to prevent travel of that flame front through the pipe 12 and into the tank. As shown in more detail in Figure 2, the flame arrestor 16 has an inlet 18 and an outlet 20. The inlet  
15 has a coupling flange 22 and as well the outlet has a coupling flange 24 to facilitate in the normal manner coupling of the flame arrestor to the pipe in which flames are to be arrested. It is apparent however from the section of Figure 2 and from the following discussion  
20 of various embodiments of the invention that the flame arrestor is bi-directional so that the inlets and outlets for the arrestor can be reversed. However, in order to facilitate discussion of the unit, the inlets and outlets will be referred to on the basis of it having been  
25 positioned in a pipe to define the direction of flow being that of arrows of 26 and 28.

On the inlet side of the flame arrestor is a chamber 30 which has a cross-sectional area approximating the entrance 32 to the flame arresting device, generally  
30 designated 34. The inlet chamber 30 is defined by a diverging cowling 36 which is of sufficient structural strength to resist failure in the event of the very high pressure detonation flame fronts. The flame  
extinguishing device 34 is housed in a cylindrical sleeve  
35 38. The cylindrical sleeve 38 has an inner surface 40 which abuts the periphery of the flame extinguishing elements to act as a seal relative to the inlet chamber



30 thereby ensuring that all gases flowing through the inlet flow solely through the flame arresting device 34. The outlet 20 has an outlet chamber 42 which reduces to the size of the outlet 20. The outlet chamber 42 is  
5 defined by a cowling 44 which is also of a material to resist the pressures of detonation flame fronts. Both the inlet and outlet cowlings 36 and 44 are provided with collars 46 and 48. The collars 46 and 48 include apertures 50 through which threaded rod 52 extends and is  
10 secured by bolts 54. This clamps the sleeve 38 in position to retain and secure the flame arresting device 34 in place. To ensure that the flame arresting device 34 is not crushed between the inlet and outlet cowlings and to also ensure that the elements are retained in  
15 position. Element supports 56 and 58 at the inlet and the outlet are provided to prevent element blow out by advancing high pressure flame fronts. The supports are sandwiched or wedged between the inlet and outlet extinguishing elements 60 and 62 and the respective  
20 collars 46 and 48.

The flame extinguishing device 34 according to this particular embodiment comprises two individual extinguishing elements 60 and 62 at the respective end portions for the device and two intermediate elements 64  
25 and 66. It is appreciated however, that depending on performance criteria, there could be as few as two elements or more than 3 or 4 elements. Each element comprises a crimped ribbon metal foil of approximately 0.01 inches in thickness. The crimped metal ribbon is  
30 wrapped about a solid mandrel 68. The crimped metal portions, as shown in Figure 3 may be annular elements 70 layered one upon the other or may be spirally wound about the mandrel 68. Further details of the crimped metal element are described with respect to the enlarged view  
35 of Figure 4. As shown in Figure 3, the outer circumferential portions 72 of the elements are contacted and encased by the inner surface 40 of the arrestor

sleeve 38. As is illustrated, the turbulence inducing or aerodynamic disturbing devices 84 have a thickness considerably less than the longitudinal length of each element. The devices are normally less than 10% of each element length and preferably have a thickness in the range of the hydraulic diameter of the element channels. Also, as shown in Figure 3, the element support 58 is a ring 74 having an inner grid defined by cross members 76 and 78. The inner face 80 of the support member abuts the outer edge of the respective element 62 in the manner shown in Figure 2. Its outer periphery 82 is positioned within the sleeve 38 which houses the elements to provide a self-contained cartridge. This self-contained feature for the flame arrestor element provides for ready repair and replacement of the flame arrestor element. The threaded rods are removed which permit dropping from the flame arrestor, the sleeve 38 along with the contained elements. The unit can be simply replaced or the elements knocked out from the sleeve and a new elements inserted. As will be discussed with respect to the remaining drawings, the design of this system facilitates the use of larger channels in the flame extinguishing elements so that the need to remove or disassemble the flame arrestor to allow cleaning thereof is significantly reduced.

As shown in Figure 4, the distinguishing aspect of this invention over the prior devices is the use of the turbulence inducing devices positioned between the elements 60, 62, 64 and 66. The turbulence inducing device 84 comprises a plurality of surfaces which redirect or interrupt the flow of the flame front from an upstream element 60 into a downstream element 64 in the direction of flow 26. The element 66 has a plurality of channels defined by the crimped metal ribbon 86 as located between wraps 88 and 90. These channels which extend in the longitudinal direction parallel to arrow 26 effect the transfer of heat from the flame front into the

elements which are made of a heat conductive metal such as copper, aluminum, stainless steel, steel alloys and the like. The channels 92 are of a hydraulic diameter which effect a sufficient redistribution of flow to  
5 optimize on the heat transfer from the advancing flame front to the elements by providing maximum possible surface area without overly restricting flow or increasing back pressure at high flow rates. In accordance with standard techniques the hydraulic  
10 diameter for the channels 92 is proportional to the cross-sectional area of the channel divided by the total wetted perimeter of the channel. The specific formula for a defined channel is understood to be

$$15 \quad \text{channel hydraulic diameter} = \frac{4 \times \text{cross section area of channel}}{\text{total wetted perimeter of channel}}$$

The channels 92 are of a length which normally causes  
20 laminar flow to result in the flame front as it flows through the length of the channel. The turbulence inducing devices 84 by redirecting or interrupting the flow of the travelling flame front cause turbulence, as indicated by eddy currents 94 to be induced in the flame  
25 front before entering the next element 64. In this way the boundary layer thickness of the laminar flowing flame front as its exits element 60 is broken up or at least drastically reduced before entering the next element to enhance significantly the heat transfer capabilities of  
30 the elements and promote flame extinction. Quite surprisingly, it has been found that by the use of these turbulence inducing elements it is not necessary to provide in combination with the crimped metal elements, any other device to handle flame extinction caused by  
35 detonation flame fronts. As will be demonstrated in the following tests, the turbulence inducing devices provide significant superior results compared to prior art

devices, and in particular, devices having crimped metal flame extinguishing elements.

With reference to Figure 5 the positioning of the turbulence inducing element 84 is shown. Preferably, the element 84 is of sufficient strength so that it may be wedged between the downstream edge portion 96 of element 60 and the upstream edge portion 98 of the downstream element 64. The turbulence inducing device 84 has effectively opposite edge portions 100 and 102 which contact edges 96 and 98 to locate the device 84 and position it and at the same time space the elements 60 and 64 apart. The element 84 has a plurality of sloped vanes 104 which obstruct the flow of gases in the direction of arrow 26 through channel 92 of element 62 into channel 92 of element 64. As already exemplified with respect to Figure 4, such positioning of the vanes 104 causes eddy currents 94 to develop so that flow into channel 92 continues to be in a turbulent manner with some flow straightening as the gases approach the downstream side of the channel 92 of the downstream element 64.

The turbulence inducing device 84, having the sloping vanes 104, may be constructed in a variety of shapes and manners. For example, expanded metal is a preferred way of producing the turbulence inducing device 84 as shown in Figure 6. Expanded metal comprises crisscrossing elements 106 and 108. The expanded metal is formed by piercing metal sheet to form parallel offset cuts and then drawing the metal apart to form the triangular shaped openings 110. In the process of drawing the metal sheet apart the crisscross members 106 and 108 can be sloped in the manner shown in Figure 5 to provide the sloping vane surfaces 104.

In view of the principal of the invention demonstrated with respect to Figures 4 and 5, it is appreciated that other types of turbulent inducing devices may be positioned between the upstream and

downstream elements. Such alternative embodiments for the elements may be in the form of devices of Figure 7 and 8. In Figure 7 a wire mesh 112 is provided having crisscross wires 114 and 116. The positioning the wire mesh and its sizing is such to obstruct the flow of the flame front from the upstream element to the downstream element so that in accordance with the action provided by the element 84 of Figure 5 turbulence is induced in the flame front before entering the channels 92 of the downstream element. Similarly, with Figure 8, a perforated plate 118 is provided having perforations 120 formed therein. The crisscross nature of the plate 122 interrupts the flow of gases from one element to the next so that in accord with the principal discussed with respect to Figures 4 and 5 turbulence is induced in the flame front before entry into the channels of the downstream flame arresting element.

It is appreciated that the sizing of the particular embodiments shown in Figures 6, 7 and 8 is chosen to ensure that maximum interruption in the flow pattern of the flame front from one element to the next is provided without significantly reducing flow rate or significantly increasing back pressure.

It is appreciated that the flame extinguishing elements of Figure 3 may have differing designs such as those shown in Figures 9, 10 and 11. In Figure 10 a tube bundle 124 is provided which comprises individual tubes 126 having the necessary hydraulic diameters to effect flame extinction. Similarly, with the parallel plate device 128 of Figure 10 the hydraulic diameter defined by the spacing 130 between plates 132 and 134 is such to effect the flame extinction. The grid system 136 of Figure 11 comprises normally, intersecting fins 138 which define the channels 140 extending through the element 136. It is understood that these designs may be made of materials other than metal, such as, plastic, ceramic, glass and the like. It is understood that the time to

extinguish the flame is usually less than one second. During this relatively short interval, the elements do not heat up to a temperature which can cause damage to them. This mass of the elements and their relative very  
5 low temperature prevents overheating of the elements.

Although not wishing to be bound by any particular theory with respect to the surprising improved performance of this type of flame arresting device, it is thought that with the prior art devices the hydraulic  
10 diameter of the channels required to effect extinction of detonation flames and types of deflagration flames promoted laminar flow of the flame front through the channels. This laminar flow develops a boundary layer of gas turbulence which significantly increases resistance  
15 of heat transfer from the flame front to the metal elements thereby requiring either increase in surface area to effect flame extinction or a several fold increase in length extension of the laminar flow channels. Contrary to that system, the turbulence  
20 inducing devices of this invention minimize boundary layer thickness in the advancing flame front within the channels so that increased heat transfer is realized and quite surprisingly to an extent which does not require any additional devices such as detonation attenuators in  
25 the unit to effect quenching of high pressure detonation flame fronts.

In view of this enhanced performance, the flame extinguishing elements used in the flame arrestor of this invention, the device can be designed with channels  
30 having hydraulic diameters which provide for more than acceptable flow and pressure drop characteristics despite their enhanced performance. This permits the designing of the straight path section of the flame arrestor elements with acceptable channel hydraulic diameters  
35 which avoids clogging and also facilitates cleaning as required. This type of element is easy to construct in a form which is capable of withstanding repeated high

pressure impacts of supersonic shock waves associated with detonation wave or flame fronts. It is also understood that the apparatus for extinguishing flames in accordance with this invention may be used with a variety of flammable gaseous mixtures. The most common applications involve the typical alkane hydrocarbon vapour mixture with air. For example, methane, propane and ethane. The invention also applies to combustible gases that are more difficult to extinguish such as ethylene, acetylene, hydrogen, hydrogen sulfide and the like. The apparatus may also be used in applications for arresting flames that include pure oxygen or oxygen enriched air which can withstand high pressure detonation flame fronts associated with such combustible mixtures. Tests have been conducted to demonstrate the superior performance of the flame arresting apparatus according to this invention. A standard test unit was used to determine pass or fail of various flame arrestor designs. The test unit is constructed in accordance with standard flame arrestor testing techniques which is briefly described as follows.

The flame arrestor test system is made up of three sections: the run-up side, the test flame arrestor and the protected side. Although the unit is briefly described here, it can be found in several reference texts and in particular, the new guidelines for the unit can be found in greater detail in Canadian Standards Associated standard 2343 (revised edition to be published March 1993). The run-up section consists of 40 feet of 3 inch steel pipe. Spark plugs are installed at 1 foot intervals along the entire length in order to permit variation of the conditions of flame arrival at the flame arrestor face. In general, the arrival pressure increases with increasing distance of ignition from the arrestor. At the end furthest from the arrestor, there is a three foot long flame accelerator to allow the generation of detonations within the limited test run-up

length. A pressure transducer is located about 6 inches from the arrestor inlet flange in order to monitor the flame arrival pressure. Also, a flame verification thermocouple is at the same distance relative to the inlet flange.

On the protected side, two different explosion venting conditions can be tested: open end and restricted end. The open end pipe is 10 feet long while the restricted end pipe is two feet long with a one half inch diameter by 6 inch long vent nipple attached to the end. A flame detection thermocouple is installed on the protected side in order to monitor flame arrestor failure. As well, a pressure transducer is used to monitor pressures on the protected side. The test procedure consists of purging the test system with a 4.2% propane-air mixture, ignition and assessment of flame arrestor performance.

In the aforementioned U.S. patent 4,909,730 a test system similar to that described above was used in testing the flame arrestors which included various types of element designs as well as the use of a detonation attenuator cup. Of the various designs tested it is interesting to note the results of tests on the element design of Figure 16 of that U.S. patent. That design consists of a plurality of individual elements stacked together without the use of an attenuator cup. The channel hydraulic diameter was approximately 0.04 inches which involved the use of a 0.05 inch crimped height for the element channels. The conclusion in testing that unit was that for detonation flame fronts, it failed.

In order to test the advantages and unexpected features of this invention it is apparent that in the prior art devices the detonation attenuator cup is required to provide a useful unit. We have therefore compared the performance of a flame arrestor design having the extinguishing elements 60, 62, 64 and 66 without the turbulence inducing devices positioned



therebetween and instead with the prior art detonation attenuator cup positioned in front of the elements in accordance with the design configuration of Figure 3 of that U.S. patent. The hydraulic diameter of the channels in the elements of the test unit having the attenuator cup without the turbulence inducing devices was the same as the hydraulic diameter of the channels in the elements of the design in accordance with this invention. The flame arrestor elements had the following characteristics:

- 1) the crimped height of the channel was 0.070 inches,
- 2) each element was approximately 2 inches thick,
- 3) each element had a diameter of 9.5 inches,
- 4) the hydraulic diameter of the channels was 0.055 inches which is 38% greater than the hydraulic diameter of 0.04 inches for the elements of the aforementioned U.S. patent 4,909,730, and
- 5) the metal foil in the crimped metal element has a thickness in the range of 0.01 inches.

Based on the above test conditions and design criteria the results are set out in Table 1 where column A is the Run-up Distance to the attenuator, that is, the distance of ignition of the gas in front of the arrestor. Columns B and C relate to the prior art device having the detonation attenuator cup and Columns D and E relate to the subject invention. In columns B and D the pressure upstream of the attenuator is measured by the pressure transducer and given in PSIG.

TABLE I

	A	PRIOR ART		C	D	E
		Pressure (PSIG)	Runup Distance ft.		Pressure (PSIG)	Pass/Fail
1	1	6.7	1	Fail	2	Pass
2	1	3.3	1	Fail	3	Pass
3	1	15	1	Fail	5.3	Pass
4	2	0.9	2	Pass	6	Pass
5	4	5	4	Pass	7.8	Pass
6	4	6.7	4	Pass	6	Pass
7	10	5	10	Pass	6	Pass
8	18	26	18	Pass	20	Pass
9	18	26.3	18	Pass	15	Pass
10	23	350	23	Fail	75	Pass
11	23	90	23	Pass	20	Pass
12	24	70	24	Pass	900	Pass
13	24	50	24	Pass	806	Pass
14	25	1129	25	Fail	250	Pass
15	25	1200	25	Fail	1000	Pass
16	25	725	25	Fail	900	Pass
17	25	2000	25	Fail	800	Pass
18	29	2000	29	Fail	500	Pass

In all situations of advancing flame type, whether it be low pressure deflagration or high pressure detonation, the device of Figure 4 performed extremely well and passed in each instance, whereas the flame  
5 arresting device common to the prior art failed on several occasions.

The prior art system used a channel hydraulic diameter of 0.04 inches. The flame arrestor according to this invention performed successfully even though the  
10 hydraulic diameter of the crimp channels was increased to 0.055 inches (38% greater) and a 90% increase in channel hydraulic area. As a result, the subject invention permits the flame arrestor to perform successfully with significantly greater channel hydraulic diameter. This  
15 design reduces clogging of the elements and reduces the pressure drop of the crimped ribbon elements by about 30%. As previously noted, equivalent relative benefits can be realized for flame arrestor applications with smaller hydraulic diameters for use with systems  
20 involving more flammable gases such as acetylene, hydrogen, ethylene, hydrogen sulphide and the like. For such very flammable gases, the hydraulic diameter may be as low as 0.005 inches which is still larger than what would be required in prior art devices. It is also  
25 understood that in some applications with less flammable gases, the hydraulic diameter may be greater than 0.05 inches up to approximately 0.10 inches.

This invention provides a more readily constructed apparatus for extinguishing travelling flames with a  
30 minimum number of components yet covers most applications and can withstand repeated high pressure detonations.

Although preferred embodiments of the invention are described herein in detail, it will be understood by those skilled in the art that variations may be made  
35 thereto without departing from the spirit of the invention or the scope of the appended claims.

WE CLAIM:

1. An apparatus for extinguishing a flame travelling along a pipe where the travelling flame is characterized as any type of deflagration flame or detonation flame, said apparatus comprising:
- i) a housing with an inlet and an outlet and means for connecting said inlet and said outlet in a pipe,
  - ii) a flame extinguishing device,
  - 10 iii) means for securing said device in said housing,
  - iv) said device including a plurality of serially arranged elements, each element having a plurality of longitudinally extending channels,
  - v) means for inducing turbulence in flow of flame through said elements, said turbulence inducing means being positioned between adjacent elements and having surfaces for inducing turbulent flow in flame exiting an upstream element before entering a downstream element to enhance thereby heat transfer from a travelling flame
  - 15 into said elements,
  - vi) said device having a sufficient number of said elements to extinguish any type of flame travelling along a pipe in which said apparatus is connected, and
  - vii) means for sealing said elements to said housing
  - 25 to direct flame flow solely through said elements and said turbulence inducing means.
2. An apparatus of claim 1 wherein said surfaces of said turbulence inducing means are adapted to disrupt flame flow exiting from said upstream element to an adjacent said downstream element.
3. An apparatus of claim 1 wherein said turbulence inducing means is a rigid component abutting adjacent elements to space apart said elements, said component having a thickness which is less than 10% of a longitudinal length dimension of said element.
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4. An apparatus of claim 1 wherein said turbulence inducing means is a rigid component abutting adjacent elements, said surfaces of said component obstructing direct flame flow from channels of said upstream element  
5 into channels of said downstream element to induce thereby turbulence in flame flow entering said downstream element.

5. An apparatus of claim 4 wherein said component  
10 comprises a plurality of angled vanes.

6. An apparatus of claim 4 wherein said component is a perforated plate.

7. An apparatus of claim 4 wherein said component  
15 comprises a wire mesh.

8. An apparatus of claim 5, 6 or 7 wherein said element is formed of crimped ribbon metal wrapped about a core in  
20 a manner to define said longitudinal extending channels having hydraulic diameters which effect flame extinction.

9. An apparatus of claim 5, 6 or 7 wherein said element is formed by parallel plates to define said longitudinal  
25 channels having hydraulic widths which effect flame extinction.

10. An apparatus of claim 5, 6 or 7 wherein said element is formed by a bundle of parallel extending tubes, each  
30 tube having a hydraulic diameter which effects flame extinction.

11. An apparatus of claim 5, 6 or 7 wherein said element is formed by a grid of intersecting plates to define said  
35 channels which are rectangular in cross-section and have a hydraulic cross-sectional dimension which effects flame extinction.

12. An apparatus of claim 5, 6 or 7 wherein longitudinal channels of said elements have an effective hydraulic diameter which is in the range of 0.005 inches to 0.10 inches.

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13. An apparatus of claim 5 wherein said element is formed of crimped ribbon metal wrapped about a core in a manner to define said longitudinally extending channels having hydraulic diameters which effect flam extinction, said vanes of said component being defined by expanded metal, said element and said components being circular and having equivalent diameters, said sealing means comprises a sleeve enveloping and contacting outer circumferential portions of said elements to direct thereby all flame flow from said inlet through said elements.

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14. An apparatus of claim 13 wherein said securing means comprises a first support grid fixed against said element at said inlet and a second support grid fixed against said element at said outlet, said housing having means at said inlet and said outlet for wedging said support grids against said respective elements.

20

FIG. 1.

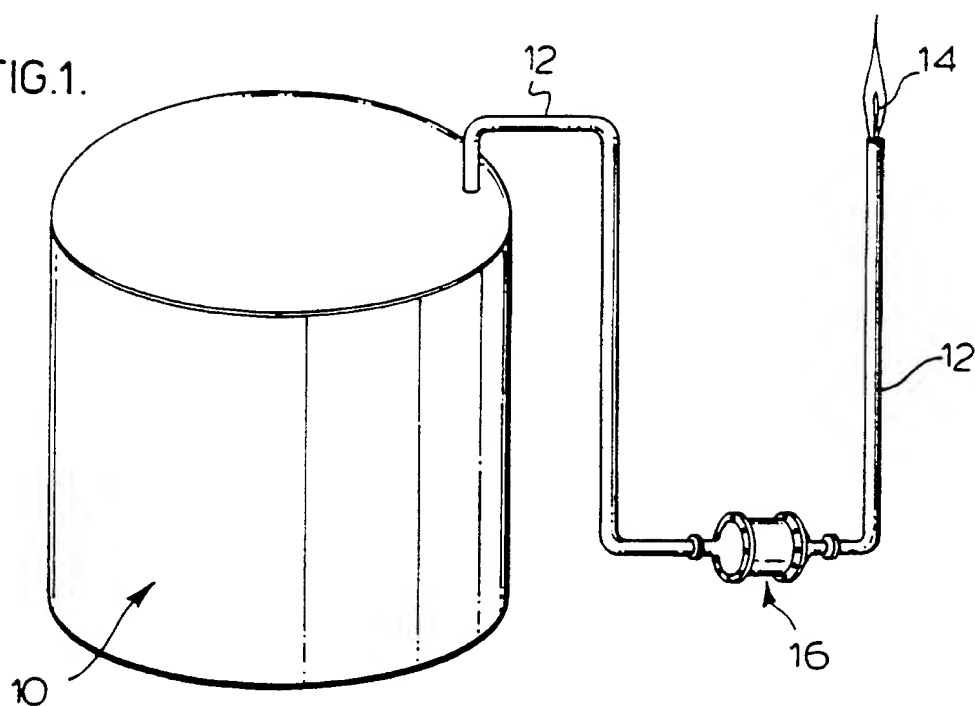
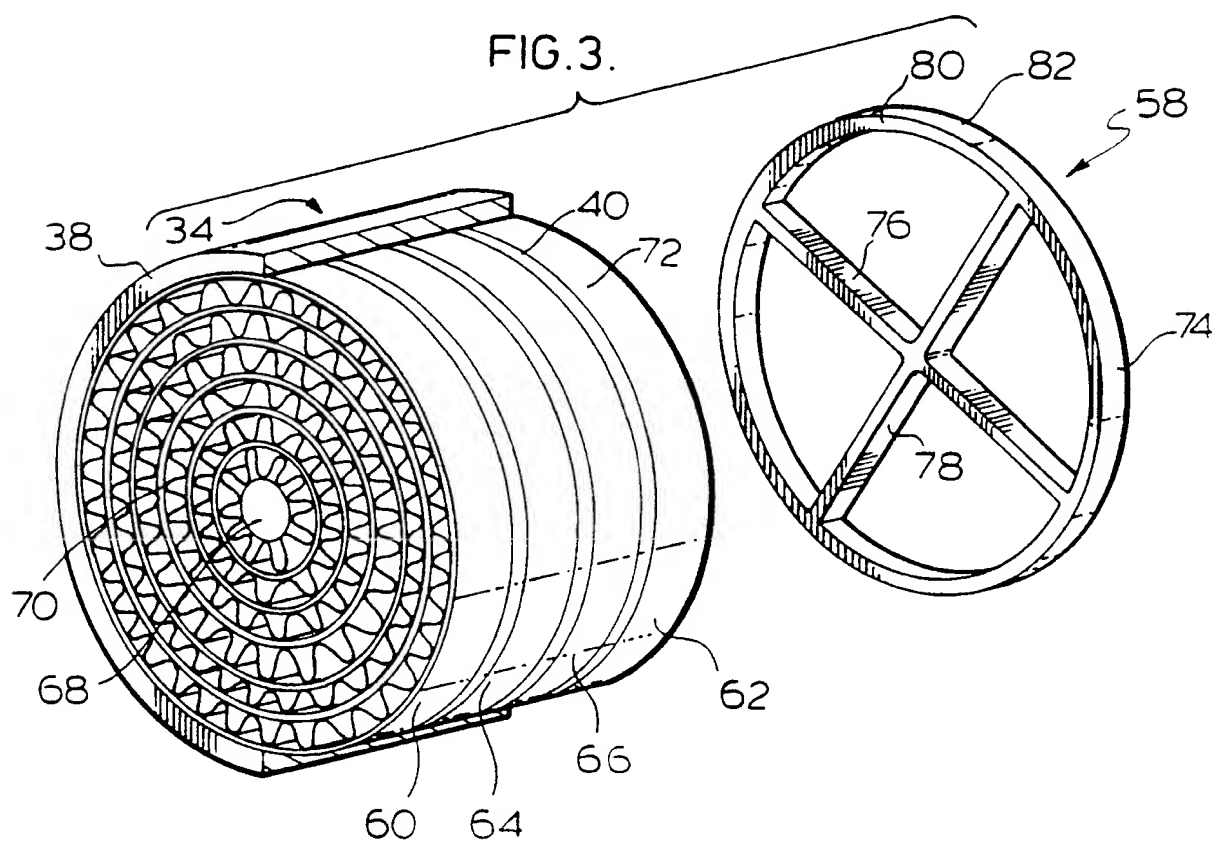


FIG. 3.



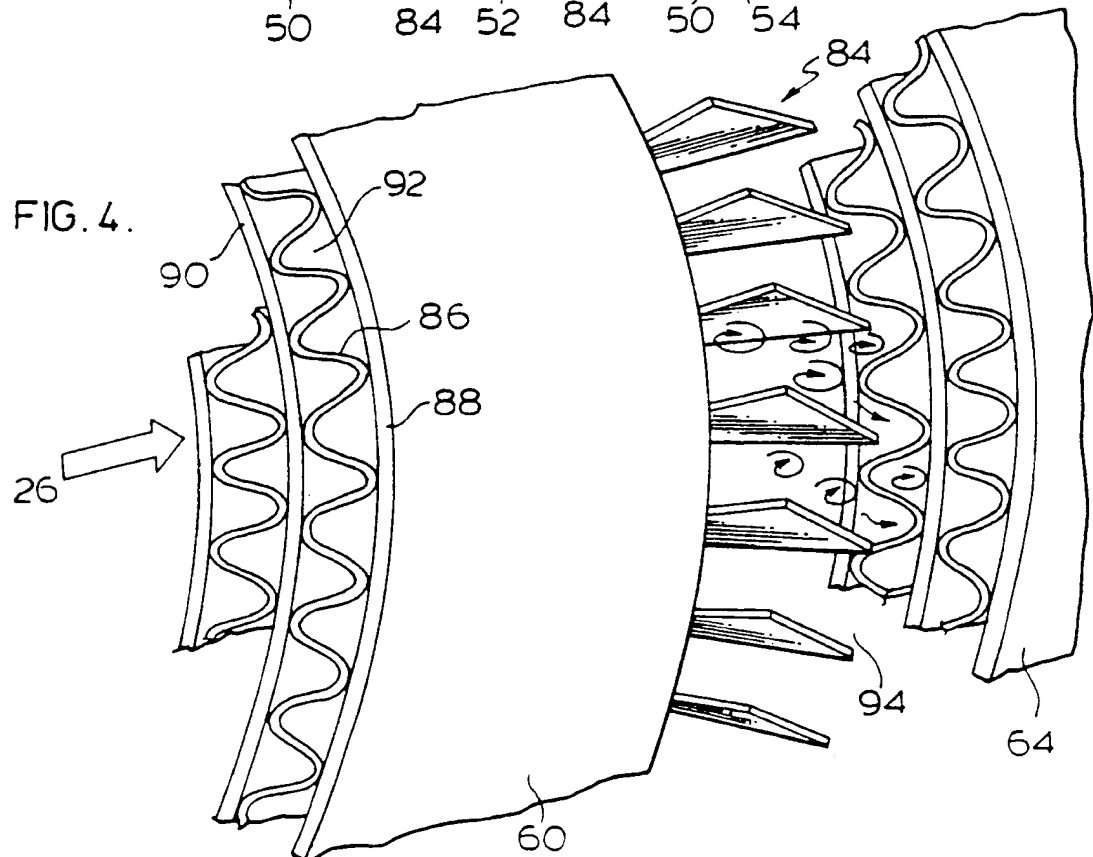
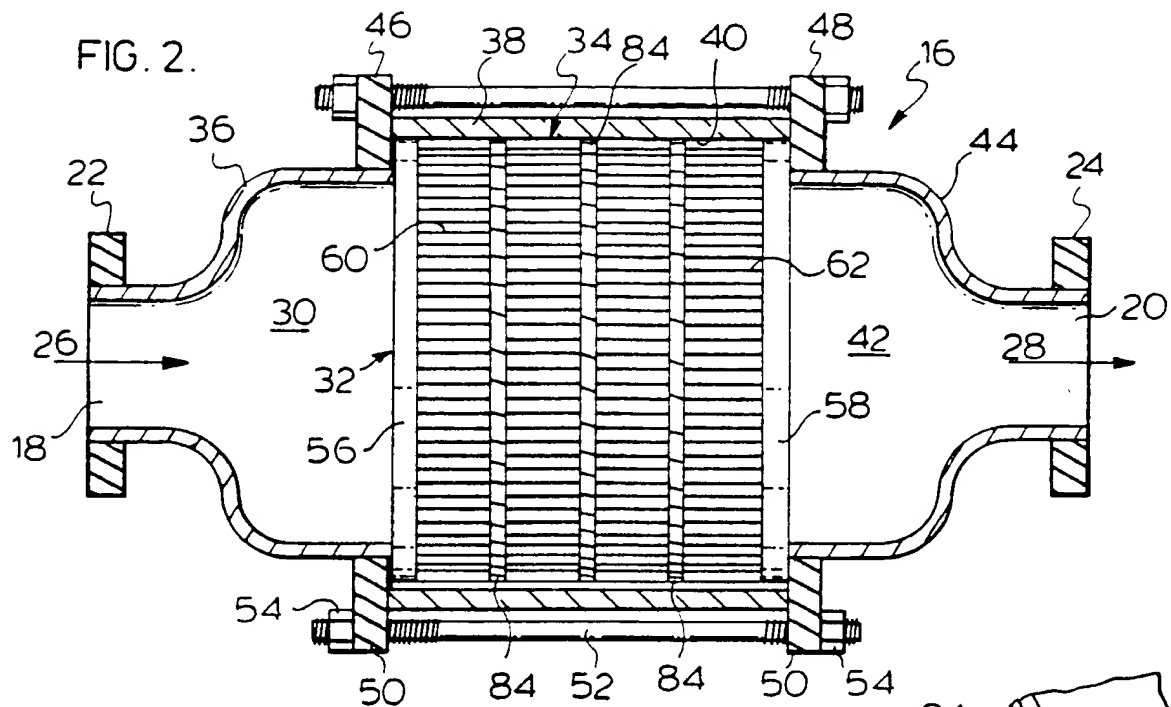




FIG.5.

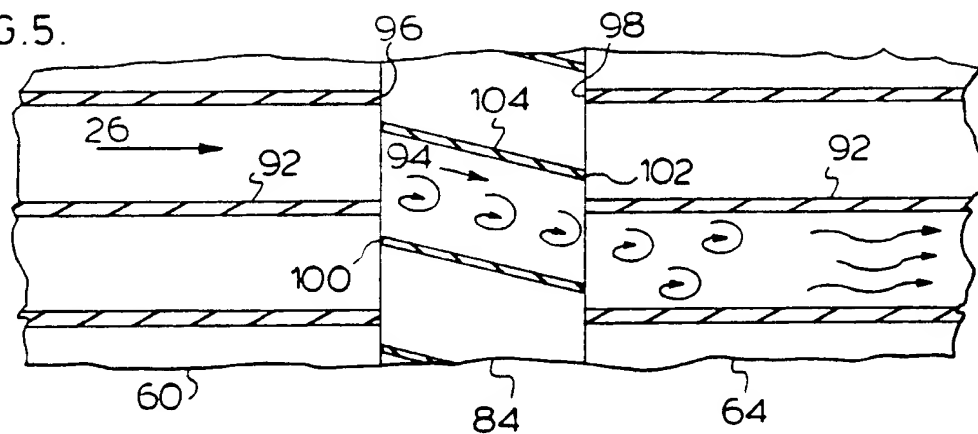


FIG.9.

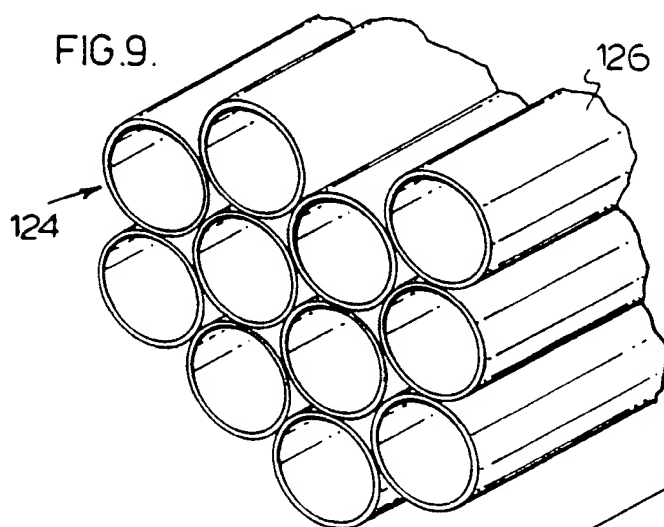


FIG.10.

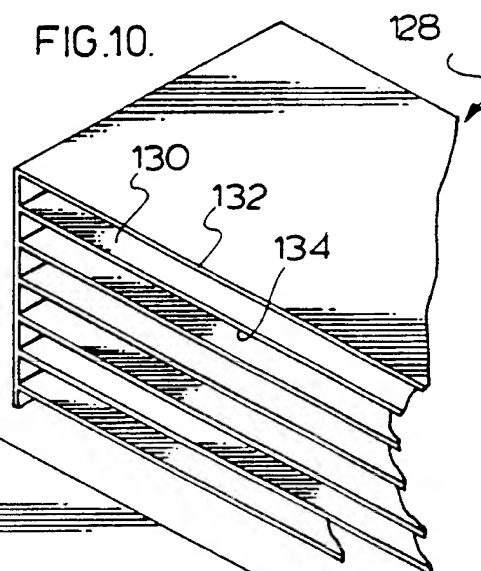
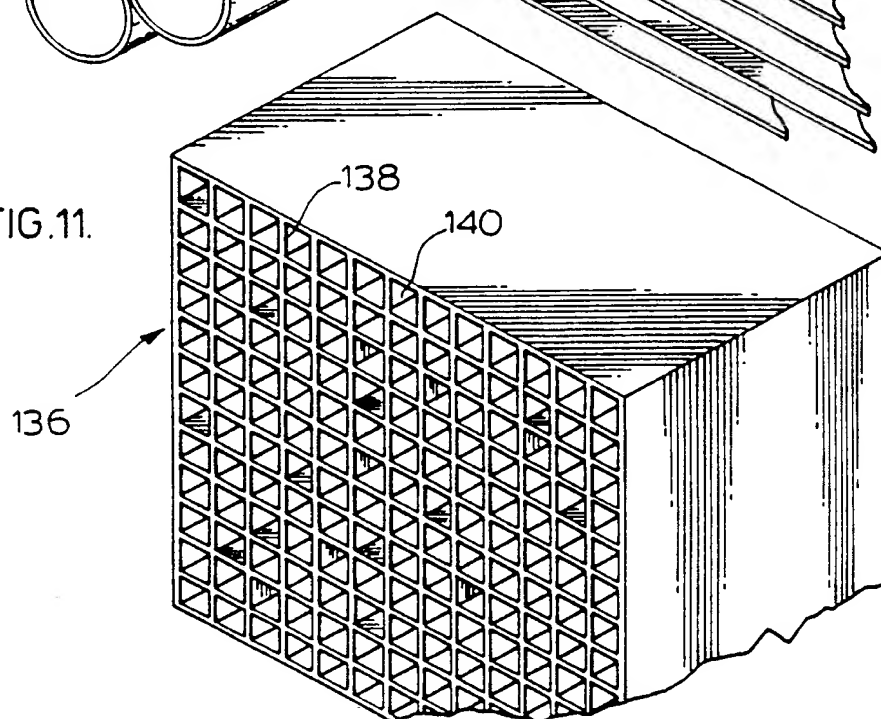
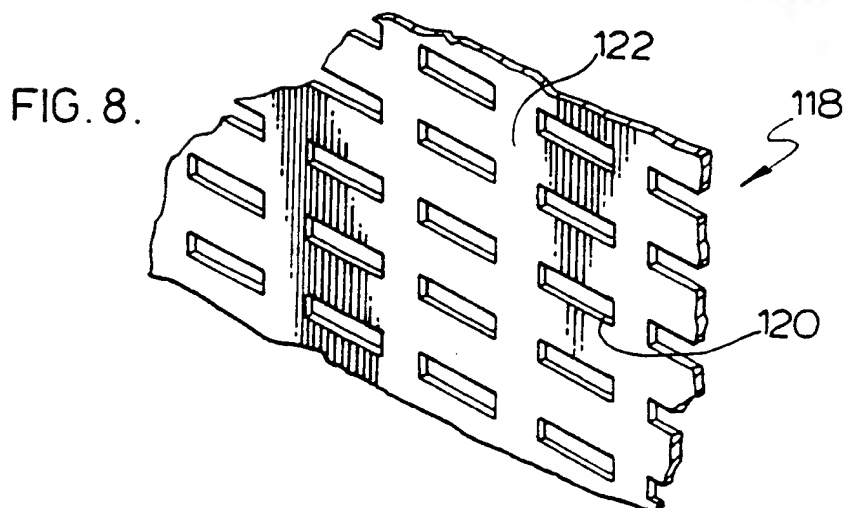
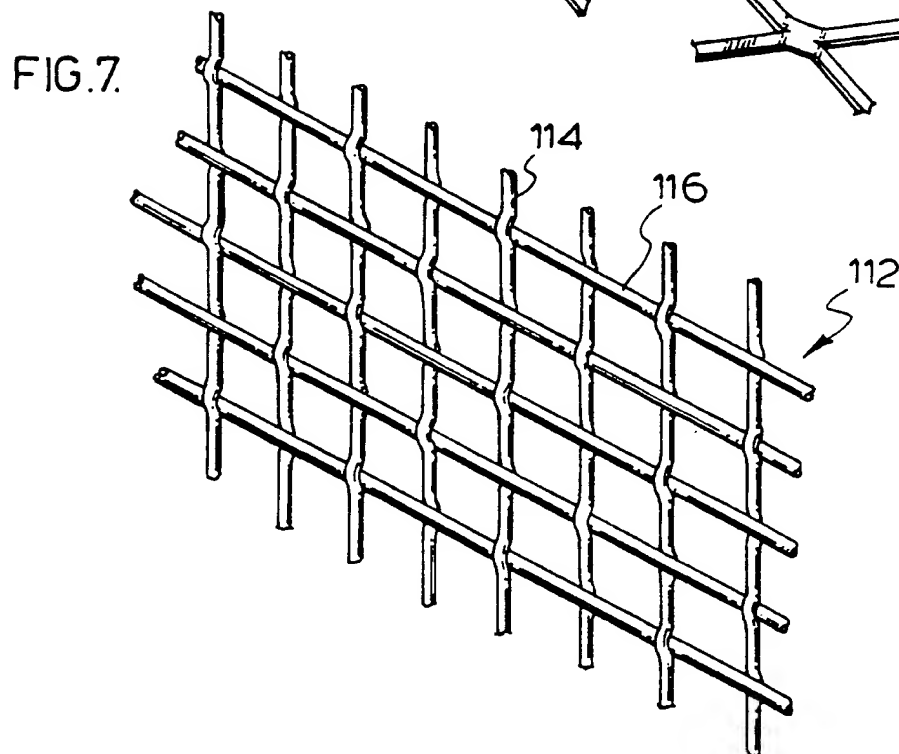
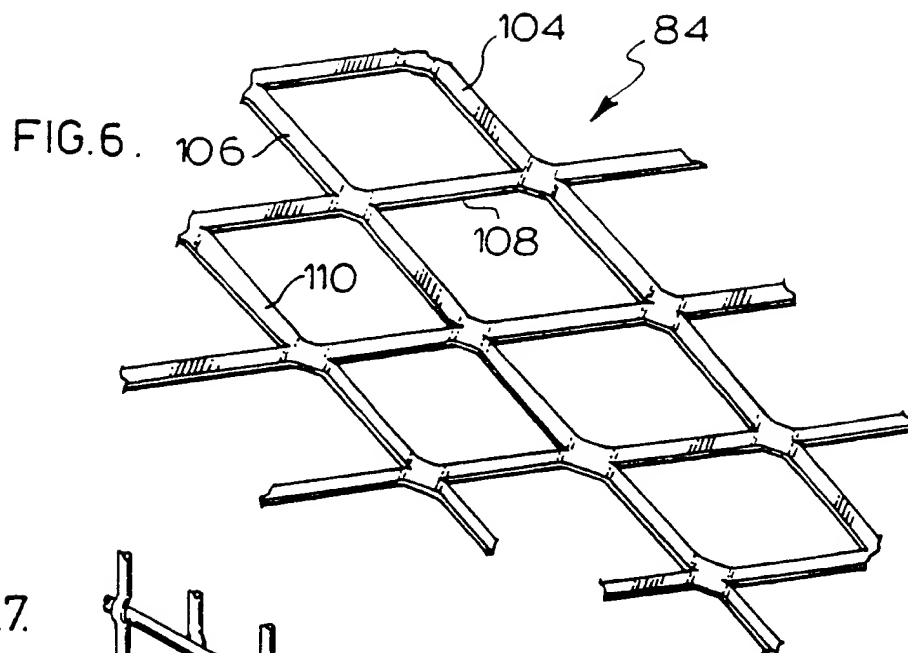


FIG.11.



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## INTERNATIONAL SEARCH REPORT

PCT/CA 93/00263

International Application No

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.Cl. 5 A62C4/00		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
Int.Cl. 5	A62C	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>		
Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
A	US,A,1 839 655 (DOBBINS) 5 January 1932 ---	1
A	DE,B,1 203 686 (NEUMANN) 21 October 1965 see the whole document ---	1
A	FR,E,457 425 (GAUMER) 9 October 1923 see the whole document ---	1
A	DE,A,2 436 206 (DIE ERBEN DES SMENTANCA) 4 August 1977 see the whole document see the whole document -----	1
<p><sup>10</sup> Special categories of cited documents : <sup>10</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
20 SEPTEMBER 1993	29. 09. 93	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	DIMITROULAS P.	

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ON INTERNATIONAL PATENT APPLICATION NO.

CA 9300263  
SA 75738

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20/09/93

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-1839655		None	
DE-B-1203686		None	
FR-E-457425		None	
DE-A-2436206	04-08-77	None	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82